Application Note No. 003

Solar Inverter String Design Calculations

Version History

- Version 01(2020-05-20)
  Initial Release

The following article will help you calculate the maximum/minimum number of modules per series string when designing your PV system. And the inverter sizing comprises two parts, voltage, and current sizing. During the inverter sizing you need to take into account the different configuration limits, which should be considered when sizing the solar power inverter (Data from the inverter and solar panel data sheets). During the sizing, the temperature coefficient is an important factor.

1. Solar panel temperature coefficient of Voc/ Isc:

The voltage/current that solar panels work at is dependent on the cell temperature, the higher the temperature the lower the voltage / current the solar panel will produce, and vice versa. The voltage/current of the system will always be at its highest in the coldest conditions and for example, the solar panel temperature coefficient of Voc is required to work this out. With mono and polycrystalline solar panels, it's always a negative %/^{o}C figure, such as -0.33%/^{o}C on the SUN 72P-35F. This information can be found on the solar panel manufacturers' data sheet. Please refer to figure 2.

2. No. of solar panels in the series string:

When solar panels are wired in series strings (that is the positive of one panel is connected to the negative of the next panel), the voltage of each panel is added together to give the total string voltage. Therefore we need to know how many solar panels you intend to wire in series.

When you have all the information you are ready to enter it into the following solar panel voltage sizing and current sizing calculations to see if the solar panel design will suit your requirements.

➢ Voltage Sizing:

Max panel's voltage =Voc*(1+(Min.temp-25)*temperature coefficient(Voc)

Max number of Solar panels=Max. input voltage / Max panel's voltage

➢ Current Sizing:

Min panel's current =Isc*(1+(Max.temp-25)*temperature coefficient(Isc)

Max number of strings=Max. input current / Min panel's current

3. Example:

Curitiba, the city of Brazil, the customer is ready to install one Renac Power 5KW three-phase inverter, the solar panel model is a 330W module, the minimum surface temperature of the city is -3 ℃ and the maximum temperature is 35 ℃, the open circuit voltage is 45.5V, Vmpp is 37.8V, the inverter MPPT voltage range is 160V-950V, and the maximum voltage can withstand 1000V.

Inverter and datasheet:

Model	R3-4K-DT	R3-5K-DT	R3-6K-DT	R3-8K-DT	R3-10K-DT	R3-12K-DT	R3-15K-DT
DC Input Data							
Max. Recommended PV Power	5200 Wp	6500 Wp	7800 Wp	10400 Wp	13000 Wp	15600 Wp	19500 Wp
Maximum DC Input Voltage	1000 V						
MPPT Voltage Range	160 ~ 950 V			250 ~ 950 V			
Start-up Voltage	160 V			200 V			
No. of MPP Trackers	2						
No. of Input Strings Per Tracker	1/1						2/1
Max. DC Input Current	12.5 A /12.5 A						20A /12.5 A
DC Switch	Integrated						

Figure 1

Solar panel datasheet:

ELECTRICAL CHARACTERISTICS					
Maximum Power At STC(Pmax)	320W	325W	330W	335W	340W
Short Circuit Current(Isc)	9.03A	9.10A	9.22A	9.31A	9.37A
Open Circuit Voltage(Voc)	44.6V	44.9V	45.5V	46.1V	46.4V
Maximum Power Current(Impp)	8.53A	8.62A	8.73A	8.82A	8.90A
Maximum Power Voltage(Vmpp)	37.5V	37.7V	37.8V	38.0V	38.2V
Module Efficiency	16.58%	16.84%	17.09%	17.35%	17.61%
Power Tolerance	0~+3%	0~+3%	0~+3%	0~+3%	0~+3%

TEMPERATURE CHARACTERISTICS	
Norminal Operating Cell Temperature(Noct)	45℃±2℃
Temperature Coefficient Of Pmax	-0.41%℃
Temperature Coefficient Of Voc	-0.33%℃
Temperature Coefficient Of Lsc	0.06%℃

Figure 2

A) <u>Voltage Sizing</u>

At the lowest temperature (location dependent, here -3°C), the open-circuit voltage V_{oc} of the modules in each string must not exceed the maximum input voltage of the inverter (1000 V):

- **Calculation of the Open Circuit Voltage at -3°C:**

$$V_{OC\ (-3°C)} = 45.5*(1+(-3-25)*(-0.33\%)) = 49.7\ Volt$$

- **Calculation of N the maximum number of modules in each string:**

N = Max input voltage (1000 V)/49.7 Volt = 20.12 (always round down)

The number of solar PV panels in each string must not exceed 20 modules
Besides, at the highest temperature (location dependent, here 35°C), the MPP voltage VMPP of each string must be within the MPP range of the solar power inverter (160 V – 950 V):

- **Calculation of the maximum Power Voltage VMPP at 35°C:**

$$V_{MPP\ (35\ °C)} = 45.5*(1+(35-25)*(-0.33\%))= 44\ Volt$$

- **Calculation of the minimum number of modules M in each string:**

M = Min MPP voltage (160 V)/ 44 Volt = 3.64(always round up)

The number of solar PV panels in each string must be at least 4 modules.

B) Current Sizing

The short circuit current I_{SC} of the PV array must not exceed the allowed maximum Input current of the solar power inverter:

- **Calculation of the maximum Current at 35°C:**

$$I_{SC\,(35\,°C)} = ((1+ (10 * (TC_{SC}/100))) * I_{SC}) = 9.22*(1+(35-25)*(-0.06\%))= 9.16\ A$$

- **Calculation of P the maximum number of strings:**

P = Maximum input current (12.5A)/9.16 A = 1.36 strings (always round down)

The PV array must not exceed one string.

Remark:

This step is not required for the inverter MPPT with only one string.

C) Conclusion:

- The PV generator (PV array) consists of **one string**, which is connected to the three-phase 5KW inverter.
- In each string, the connected solar panels should be **within 4-20 modules**.

Remark:

Since the best MPPT voltage of the phase inverter is around 630V (the best MPPT voltage of the single phase inverter is around 360V), the working efficiency of the inverter is the highest at this time. So it is recommended to calculate the number of solar modules according to the best MPPT voltage:

$$N = Best\ MPPT\ V_{OC} / V_{OC\,(-3°C)} = 756V/49.7V=15.21$$

Single crystal panel Best MPPT V_{OC}=Best MPPT voltage x 1.2=630x1.2=756V
Polycrystal panel Best MPPT V_{OC}=Best MPPT voltage x 1.2=630x1.3=819V

So for Renac three-phase inverter R3-5K-DT, the recommended input solar panels are 16 **modules** and just need to be connected to one string 16x330W=5280W.

4. Conclusion

Inverter input No of solar panels depends on cell temperature and temperature coefficient. The best performance is based on the best MPPT voltage of the inverter.